The impact of tourism on soils in Zhangjiajie World Geopark

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Abstract: The soil hardness, soil water content and soil bulk density along the trails of six scenic spots in the Zhangjiajie World Geopark were measured and analyzed, and the integrated effects of tourism trampling on soils were evaluated for each scenic spots by calculating its soil impact indexes (SII) in the park. The results indicated that visitors' activities caused a serious influence on the soil in the park, especially in the two most used scenic spots-- Yellowstone Village and Gold Whip Stream. The impact of tourism on soil mainly occurred within 3 m along the trails. The impact shapes are classified into six type as single-sided node type, double-sided node type, cross node type, single-sided linkage type, double-sided linkage type and short-cut linkage type. Of six types of impact shapes, the single-sided node type and double-sided type were dominant. The average water contents of soil for six scenic spots at sample areas of 1 m, 2 m and 3 m from trial is 36.6%, 24.5% and 2.2% lower than that of the control area, respectively. The average soil hardness for six scenic spots at 1m, 2 m, and 3m from the trails tramped increased 167.9%, and 122.2%, and 15.8%, respectively, compared with the control area. Soil bulk density increased 26.5% at 1 m and 20.9% at 2 m from the trails. The main countermeasures for reducing the range and extent of tourism impact on soil are discussed.

Keywords: Tourism; Zhangjiajie World Geopark; Tourism impact; Impact shapes; Soil impact indexes; Soil bulk density; Soil hardness

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Introduction

In recent years, with the rapid development of Eco-Tourism industry in the world, the ecological environment problems in the scenic spots become increasingly outstanding. Tourism impact on the ecological environment has drawn great attention from ecologists. Some researchers have already made some fruitful work concerning the impacts of tourism on soil organic matter, soil water content, soil structure, soil section and soil erosion, etc. (Settergren and Cole 1970; Liddle and Smith 1975; Guang *et al*. 1999; Feng 1999; Guang *et al.* 2000; Tina *et al*. 2004).

Zhangjiajie World Geopark is in the northwest of Hunan Province, China. It consists of Zhangjiajie National Forest Park, Tianzi Mountain Natural Protected Area and Shuoqiyu Natural Protected Area. In February, 2004, Zhangjiajie World Geopark was placed into the first list of World Geoparks by United Nation's Educational, Scientific, and Cultural Organization (UNESCO) (Qiao 2004). The award made it more flourishing and became one of the Chinese popular tourist centers. In 2005, the park received a total of 1.5 million tourists, who brought the park with revenue of RMB1.39 billion Yuan. However, the increasing tourists brought negative impacts on air, soil, vegetation, water body, animal, sight, etc. (Wang and Hao 1988; Shi *et al* 2002a,b,c). In this study, on the basis of the analysis of the shapes and ranges of soil sections that affected by visitors, we investigated the soil hardness, soil water content and unit weight of soils along the trails in the park, evaluated the composite effects on soils in each scenic spots by calculating their soil impact indexes(SII), and put forward the countermeasures for environmental management and harness, in order to offer references for the management of tourist resources in the park.

Study method

Investigation sampling

The investigations were conducted along the six scenic spots, as Yellow Stone Village Trail, Golden Whip Stream Trail, Kidney Stockade Trail, Pipa Stream Trail, Shadao Ravine Trail and Yuanjiajie Trail in Zhangjiajie World Geopark. Since field investigation shows that the impacts of tourism on soil mainly occurred within three meters along the trails, the soil continuous gradient sections of soil samples were set within five meters along the trail. Three representative sections for each scenic spot were selected as the samples areas, and in each section, five soil samples were taken by using ring knife according to the diagonal method. Soil samples were weighed by balance and the unit weight was calculated. We took 5-g soil from each sample and mix them well, then took about half of the soil by diagonal method and calculated the water content by rapid burning method, and finally we determine the soil hardness by sclerometer (Zhuang and Nan 1978).

Assessment method

Single factor impact analysis

The differences of average water content, hardness and unit weight of soil at different distances to the trail were analyzed and compared based on the reference value in various scenic spots. The water content, hardness and unit weight of the soil in different scenic spots were calculated by using the Equation (1):

$$SCR = \frac{N_i - N_0}{N_0} \times 100 \qquad (1)$$

Where N_i and N_o are the soil factor value in i region and control site, respectively. SCR is the soil change rate (water content, hardness, unit weight).

Assessment of composite effects

The impacts of trampling on soil may be different in different

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scenic spot and for different soil factors. In the previous studies, no composite model was used to reflect the impact of tourism tramping on the soil. In this study, on the basis of the characteristic outside the soil impaction in various scenic spots in the park, we bring forward the following assessment model (Eq. 2) to assess the impacts. We weight the average change rate in various spots to obtain the soil impact index and evaluate the degree.

$$SII = \sum_{i=1}^{3} \omega_i \sum_{j=1}^{3} \frac{\left| N_{ij} - N_{0j} \right|}{N_{0j}} \qquad (2)$$

where N_{ij} and N_{0j} are the measured value of the j factor in the i region and the control region, respectively. ω_i is the weighting, *SII* is the soil impact index.

Taking consideration that the changes of the various factors by the impaction soil may occur in 1 m or 2 m sample area, especially in the 1 m sample area, we assume the weighting as 0.5, 0.3 and 0.2 for the 1-m, 2-m and 3-m sample areas, respectively, from the trail, substitute them into the Eq. 2 and calculate the composite impact index for each scenic spot in the park.

Results and analysis

Impact shape on soil

The tourism tend to concentrate on several trails and rest places in which nodes and linkages resulting from intense trampling are formed. Generally speaking, nodes of impact occur at reception center and rest places, such as encampment, fire camping, and scenic spot, etc.. Linkage developed along the trail between nodes (Liddle and Smith 1975; Liu 1989). Each reception center, rest place and trail has the same impact shape. The impact shape was divided into six types according to the position and shape (Fig. 1).

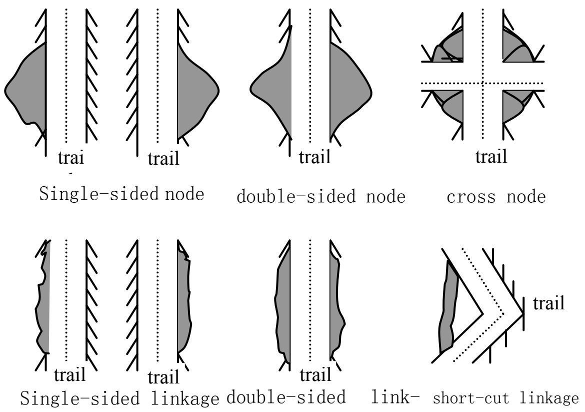

Fig. 1 Impact shape of the affected soil alone the trails

.The single-sided node type is the most frequent one, and often occurs near scenic spots of the hillside. The quantity of double-sided type is relative small and often occurs on the smooth section. The cross node type is most likely to occur at the road crossing. The single-sided node type also occurs at the slope. The double-sided type is mainly formed at broad flat trail while the short-cut linkage type is mainly formed at the corner of the trail.

The quantities of nodes and linkages in Yellowstone Village Trail and Gold Whip Stream Trail are largest. The main reason is that Yellowstone Village Trail and Gold Whip Stream Trail are the two main scenic spots in the park. Accordingly, they have more sight spots and their visiting rate is rather high, which bring heavily tramping and thus the area of nodes and linkages there are bigger. The visiting rate in the other four scenic spots is lower and the quantity of nodes and linkage is smaller, the trampling extent is minor, and the area of nodes and linkages is smaller.

The impact range on soil in the park

From the diagnoses results concerning the water content, hardness and bulk density of soil in the continuous gradient at the outer edge of the trail (as Fig. 2, Fig. 3, Fig. 4), we can know that, the impacts on soil mainly occurred within three meters along the trails, and the indexes of soil vary little at the range more than three meters.

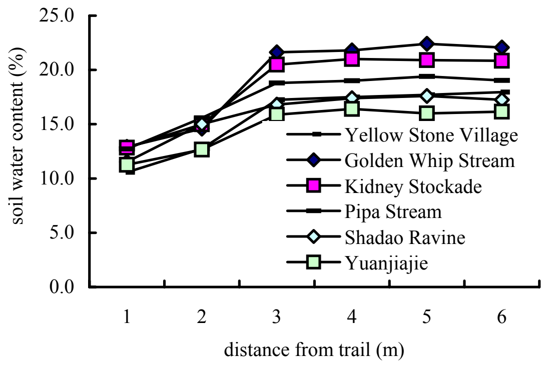

Fig. 2 Soil water content rate of each continuous sample section soils

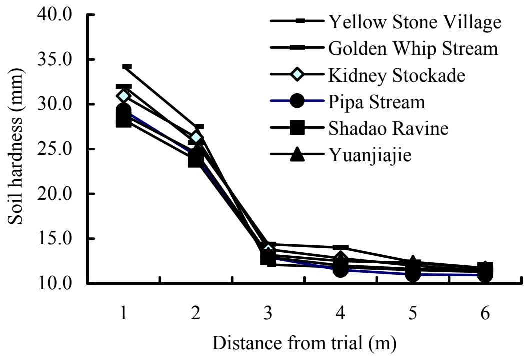

Fig.3 Soil hardness of each continuous sample section soils

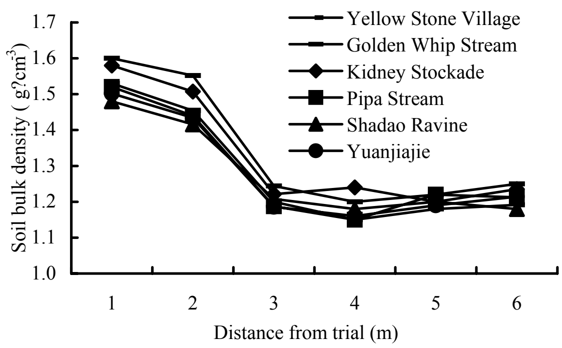

Fig.4 Soil bulk density of continuous sample section soils

Tourism impacts on soil water content

The change of soil water content may be different under different external force of tramping. For loam and clay soil, the trampling reduces the porosity, thus decreasing the moisture capacity and water content of soil (Settergren and Cole 1970; Liu and Zhang 1997). But for the heavy sandy soil, trampling makes the non-capillary which can not hold water originally change into capillary which can hold water, This will lead to the increase of soil water content. The soil in Zhangjiajie World Geopark is mainly sandy soil with middle thickness yellow earth. The trampling compacts soil and reduces the water content of soil. The average water contents of soil at sample areas of 1 m, 2 m and 3 m from trial is around 12%, 14% and 18%, respectively (Table 1), which is 36.6%, 24.5% and 2.2% lower than that of the control area, respectively.

The soil water content of Yellow Stone Village is the lowest in range of 1–2 m from trail among the six scenic spots, which is likely associated with the slope and lower moisture capacity, but the biggest slip of water content of sample area is undoubtedly related to the most frequently visitors and the heaviest trampling. .In Yuanjiajie the water contents of soil at 1 m and 2 m from from trail are 30.3% and 21.7% lower than those in controls. The low water content of soil in Yuanjiajie may be related to the impacting points that are in the wide flat ground with low forest coverage and bad water reservation ability. The lower variation in soil water content in the sample area of Yuanjiajie is related to the flat land and later development as well as the lower frequent visiting. In Golden Whip Stream which has the same amount of visitors as Yuanjiajie, the soil water content is higher than that of Yellow Stone Village (Table 1). The main reason is that it is near the branch water of the trail with high groundwater table, and the surface layer soil is accessible for the water from the subjacent soil. The soil water content in Golden Whip Stream within 1m and 2m from the sample area are 41.4% and 33.8% lower than those in controls, which shows that high dense tramping will sharply reduce the soil water content in Golden Whip Stream.

Tourism impacts on soil hardness

Literature showed that, the trampling makes soil more compact and increases the hardness (Liu *et al*. 1998). Our investigation showed that the soil hardness within 2 m (average) from the trail was visibly increased (Table 2). The average soil hardness of for six scenic spots is 30.6 cm, 25.4 cm, and 13.2 cm at 1 m, 2 m, and 3 m from the trails tramped, with an increasing rate of 167.9%, 122.2%, and 15.8%, respectively, compared with the control area. The average hardness with 3m from the sample area is 13.2 cm, which increases 15.8% compare with the control sample area. It showed that the hardness between sample area and control sample area was approximate, and the impacts on soil hardness mainly occurred in the area of 1–3 m from the trails.

Among the six scenic spots, the increasing rate of the soil hardness for Yellow Stone Village scenic spot is the highest and that for Shadao Ravine scenic spot is the lowest. The former and latter is related to the most and least amount of visitors.

Table 1. Soil water content at different distances from the trail in Zhangjiajie World Geopark

Scenic spots	Soil water content (%)						
	1 m		2 m		3 m		Control
	Value	*SCR*(%)	Value	*SCR*(%)	Value	*SCR*(%)	Value
Yellow Stone Village	10.57	-41.1	12.74	-29.1	17.24	-4.0	17.96
Golden Whip Stream	12.92	-41.4	14.60	-33.8	21.62	-2.0	22.06
Kidney Stockade	12.84	-38.4	14.99	-28.1	20.49	-1.7	20.85
Pipa Stream	12.73	-33.1	15.58	-18.1	18.80	-1.2	19.03
Shadao Ravine	11.52	-33.2	15.00	-13.0	16.80	-2.6	17.24
Yuanjiajie	11.26	-30.3	12.66	-21.7	15.88	-1.7	16.16
Average	11.97	-36.6	14.26	-24.5	18.47	-2.2	18.88

Table 2. Soil hardness degree at different distances from the trail in Zhangjiajie World Geopark

Scenic spots	Soil hardness (cm)						
	1 m		2 m		3 m		Control
	Value	SCR(%)	Value	SCR(%)	Value	SCR(%)	Value
Yellow Stone Village	34.2	203.0	27.5	143.7	12.1	7.2	11.3
Golden Whip Stream	32.0	173.0	25.7	119.3	14.4	22.7	11.7
Kidney Stockade	30.9	171.2	26.3	130.7	13.8	21.0	11.4
Pipa Stream	29.3	168.2	24.3	122.4	12.9	18.3	10.9
Shadao Ravine	28.3	145.7	23.8	107.0	12.9	12.3	11.5
Yuanjiajie	28.8	147.2	24.6	111.0	13.2	13.0	11.7
Average	30.6	167.9	25.4	122.2	13.2	15.8	11.4

Tourism impacts on soil bulk density

The soil bulk density is related not only to the ingredients of solid matter, but also to the structure and the water content. For the same kind of soil, the more compact the structure is, the higher the water content, and the lower the bulk density is. Compared with the reduced water content and increased hardness after soil being impacted, the change of bulk density after tramping is more complex. On one hand, the tramping will make the soil compact and cause bulk density increased; On the other hand, usually, the soil water content will be reduced (sandy soil is not included) after tramping, which will cause bulk density reduced. The increase or decrease of bulk density after tramping depends on the variation mentioned above. Generally speaking, the increase of bulk density caused by the compaction will exceed the decrease caused by the water content decreasing. As a result, the whole bulk density seems to be increased. This can be

seen from Table 3. For all the scenic spots in Zhangjiajie World Geopark, bulk densities at 1 m and 2 m from the trails were bigger than those in controls, with an increase rate of 26.5% at 1m and 20.9% at 2 m from the trails.

Table 3. Soil bulk density at different distance from the trails in Zhangjiajie World Geopark

Scenic spots	Soil bulk density ($g•cm^{-3}$)						
	1 m		2 m		3 m		Contrast
	Value	SCR(%)	Value	SCR(%)	Value	SCR(%)	Value
Yellow Stone Village	1.56	31.3	1.48	24.2	1.20	0.7	1.19
Golden Whip Stream	1.64	30.9	1.53	22.1	1.24	-0.5	1.25
Kidney Stockade	1.58	27.9	1.51	22.0	1.22	-1.1	1.24
Pipa Stream	1.52	25.4	1.44	18.8	1.19	-2.1	1.21
Shadao Ravine	1.48	25.4	1.42	20.0	1.21	2.4	1.18
Yuanjiajie	1.50	23.7	1.43	18.1	1.19	-2.3	1.21
Average	1.54	26.5	1.47	20.9	1.21	-0.5	1.21

The soil bulk density at 1 m and 2 m from the trails is highest in Golden Whip Stream, which is likely related to the compacted soil and high water content in the impacting points of Golden Whip Stream Trail, and lowest in Shadao Ravine. The reason why bulk density in the impacting points of Yellow Stone Village is lower than that in Golden Whip Stream lies in the fact that the water content of soil in Golden Whip Stream is higher. However, the change rates within 1 m and 2 m from the sample area in Yellow Stone Village is 30.9% (at 1m) and 22.1% (at 2m) higher than those in Golden Whip Stream, Consequently, the biggest impacts on soil bulk density occurred in Yellow Stone Village and the smallest occurred in Yuanjiajie.

Integrated effects of Tourism on soil

The composite impact indexes on the soil of each scenic spots in Zhangjiajie World Geopark were calculated by using the assessment model of Eq. (2). The results are as follows:

Yellow Stone Village	2.0	Pipa Stream	1.7
Golden Whip Stream	1.8	Shadao Ravine	1.4
Kidney Stockade	1.8	Yuanjiajie	1.5

From the composite impact indexes, we can know that tourism tramping have made greater impacts on soil in Yellow Stone Village and Golden Whip Stream Trail. Thus, effective measures should be taken to reduce the tourism impact on the soil in the two scenic spots.

Conclusion and discussion

Tourists have brought a great impact on the soil hardness, soil water content and soil bulk density at the outer edge of the trails in Zhangjiajie World Geopark, particularly on soil hardness. Because forests in the park are very dense and many trails that are passing through the canyon do not have good view angle, tourists have to leave the trail to see the sights outside. Gradually the vegetation has been tramping to death, and the denudate and hardened nodes and linkages are formed. These nodes and linkages do great damage to the beauty of environment and cause a bad impression from tourists, at the same time, they are likely to lead to soil erosion and to impact the trail. In order to reduce these events, one approach is to adjust the height and close canopy of trees to improve the angle of view, such as pruning the redundant branch to form the sightseeing passage. Beautified treatment should be done in some places where the impacting nodes and linkages no doubt occur, such as laying the grass bricks to cover the bare land to beautify the landscape.

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